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Electronic Space Fire Protection: Halon 1301 Cabinet Penetration Tests

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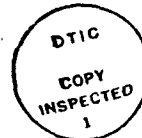
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ELECTRONIC SPACE FIRE PROTECTION: HALON 1301 CABINET PENETRATION TESTS

1.0 INTRODUCTION

This report discusses the total flooding Halon 1301 discharge tests conducted at the Aegis training facility in Moorestown, NJ. These tests were primarily conducted to evaluate the ability of Halon 1301 to penetrate typical shipboard electronic cabinets. The information gained from these tests will aid in determining the feasibility of using Halon 1301 total flooding systems for protection of shipboard electronic spaces. In no way did these tests attempt to evaluate system performance during hostile environments or evaluate the Halon 1301 total flooding system for code compliance.

2.0 PURPOSE

As an initial point, regarding fire protection, one could assume that shipboard electronic spaces are the same as shore based computer facilities. Following this rationale, one could simply apply NFPA 12A Standard on Halon 1301 Fire Extinguishing Systems [1]. In principle this approach would provide adequate fire protection, at least during peacetime steaming. However, the need for this evaluation was promulgated by several inspections of the electronics space onboard the Aegis Cruiser, USS YORKTOWN. From a fire protection standpoint these inspections revealed several key differences between shipboard electronic spaces and shore based computer facilities [2]. These key differences are:

1. interior electronic cabinet cooling schemes;
2. use or application of raised deck area; and
3. distribution of combustible cables.

In terms of shore based facilities issues 1 and 2 are somewhat related. Shore based computer facilities usually provide interior cabinet cooling by leaving the cabinet bottoms open to the raised floor area. The raised floor area is then used as an air plenum causing air conditioned room air to circulate through the cabinets. To achieve this cooling action shore based computer cabinets are generally fitted with numerous ventilation grills located throughout the cabinet's perimeter. In comparison, shipboard electronic cabinets are generally sealed at the bottom and essentially sealed around the cabinet perimeter. Openings that do exist are usually small and are provided for cable connections or tightly filtered cooling air intakes. Shipboard electronic cabinets are generally cooled in three ways. They can be:

1. totally air cooled;

2. totally water cooled; or
3. combination of air and water cooling.

Shipboard electronic cabinets that are water cooled usually do not have any openings in their exterior perimeter. These are generally consoles of the type found in Central Information Center (CIC) or Central Control Station [3]. Shipboard electronic cabinets that are air cooled, either fully or partially, obtain cooling in the same manner. This is done by interior cabinet cooling fans usually located at the cabinet top. These fans are configured to draw air conditioned room air through tightly filtered openings located near the cabinet base. The air is then circulated throughout the cabinet and discharged at the cabinet top. The used air discharges directly into an exhaust duct located above the cabinet, as shown in Fig. 1.

The distribution of combustible cables in shipboard electronic spaces is quite different from shore based computer facilities. For example, shore based computer facilities generally pass all necessary cables under the raised deck area, whereas in shipboard electronic spaces most of the necessary cables are secured to the overhead. Shipboard electronic spaces can also contain large amounts of cabling located randomly on all four walls.

Based on the information gained from inspections of the USS YORKTOWN relative to questionable areas of Halon 1301 penetration, this test program was structured to evaluate the time based Halon 1301 concentration profiles in the following areas:

1. inside electronic cabinets;
2. under raised deck areas;
3. inside large cable bundles; and
4. remainder of the electronic space.

Evaluation of this information will form the basis for reasonable presumptions regarding the performance of possible shipboard Halon 1301 total flooding systems. The specific questions to be answered by this test program are:

1. Will Halon 1301 penetrate into the above areas in sufficient time and concentration to effectively extinguish a fire?
2. What effects do the internal cabinet cooling fans have on the internal cabinet Halon 1301 concentrations?
3. What is a typical time based Halon 1301 concentration profile that can be expected in a typical shipboard electronic space?
4. Will Halon 1301 penetrate a large cable bundle?

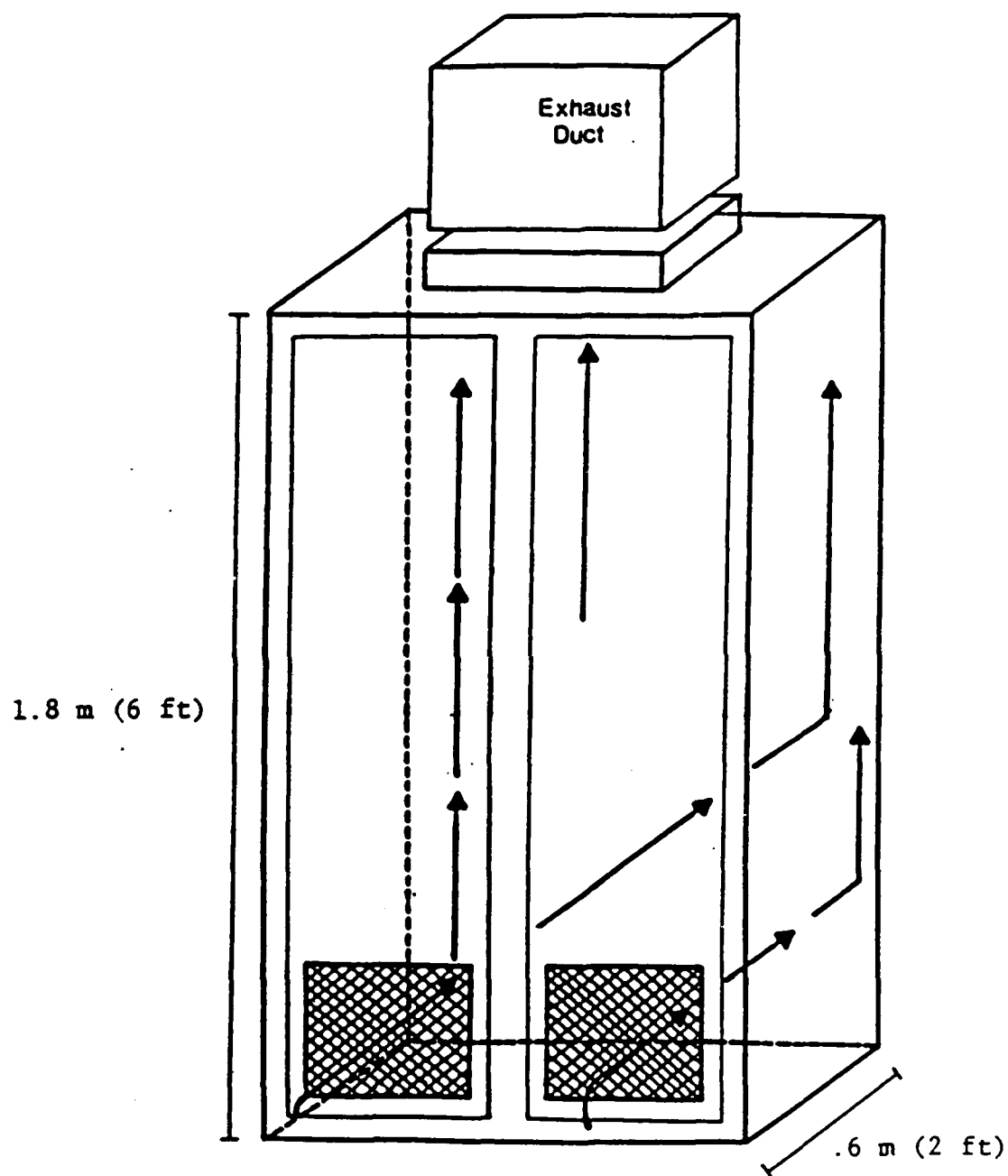


Fig. 1 - Typical shipboard electronics cabinet cooling scheme

3.0 FACILITY

The facility selected for these tests was the Combat Systems Engineering Development Site (CSEDS) for the Aegis class cruisers, CG-47, and the Aegis class destroyers, DDG-51. This site is located in Moorestown, NJ and accomodates development, testing, and crew training for the Aegis weapons systems and suites. Because the site is a crew training facility, it contains a number of combat suites and supportive electronic spaces. In addition, to enhance crew training these spaces are configured to replicate an actual ship. All of the electronic spaces at this site are protected by a total flooding Halon 1301 system, designed to provide a 6% concentration. As a result, this site represents the best possible location for tests of this nature. It provides a typical shipboard space, with the convenience of an inplace Halon 1301 total flooding system.

The specific enclosure selected within the site was Combat Systems Maintenance Central, shown in Fig. 2. This space is approximately 10 m (33 ft) x 5.2 m (17 ft) with a 2.4 m (8 ft) ceiling. The total floodable enclosure volume is approximately 124.8 m³ (4,500 ft³). Approximately half of the space contains a raised deck area that is 30.4 cm (12 in.) above the actual floor. This space contained a large cross section of electronic equipment and associated signal and power cables.

Currently this space is protected with a modular Halon 1301 total flooding system designed for a single discharge, shown in Fig. 3. The system is made up of two Halon storage/discharge spheres. One sphere is located in the space itself, while the other is mounted on an outside wall. This system was designed to provide a 6% concentration, with the outside and the inside spheres containing 40.9 kg (90 lbs) and 22.7 kg (50 lbs), respectively [4]. The system is comprised of four discharge nozzles. Three nozzles discharge directly into the space, while one nozzle discharges under the raised deck area. The space is also served by a conventional HVAC system, with dampers interlocked with the Halon system.

4.0 INSTRUMENTATION

A total of six thermal conductivity Halon 1301 analyzers were used. Each analyzer could accommodate three sampling points, thus providing a total of 18 sampling points. The six analyzers were located remote to the space as shown in Fig. 4. Transit from the actual sampling points to the analyzers was accomplished by .64 cm (.25 in.) Tygon tubing.

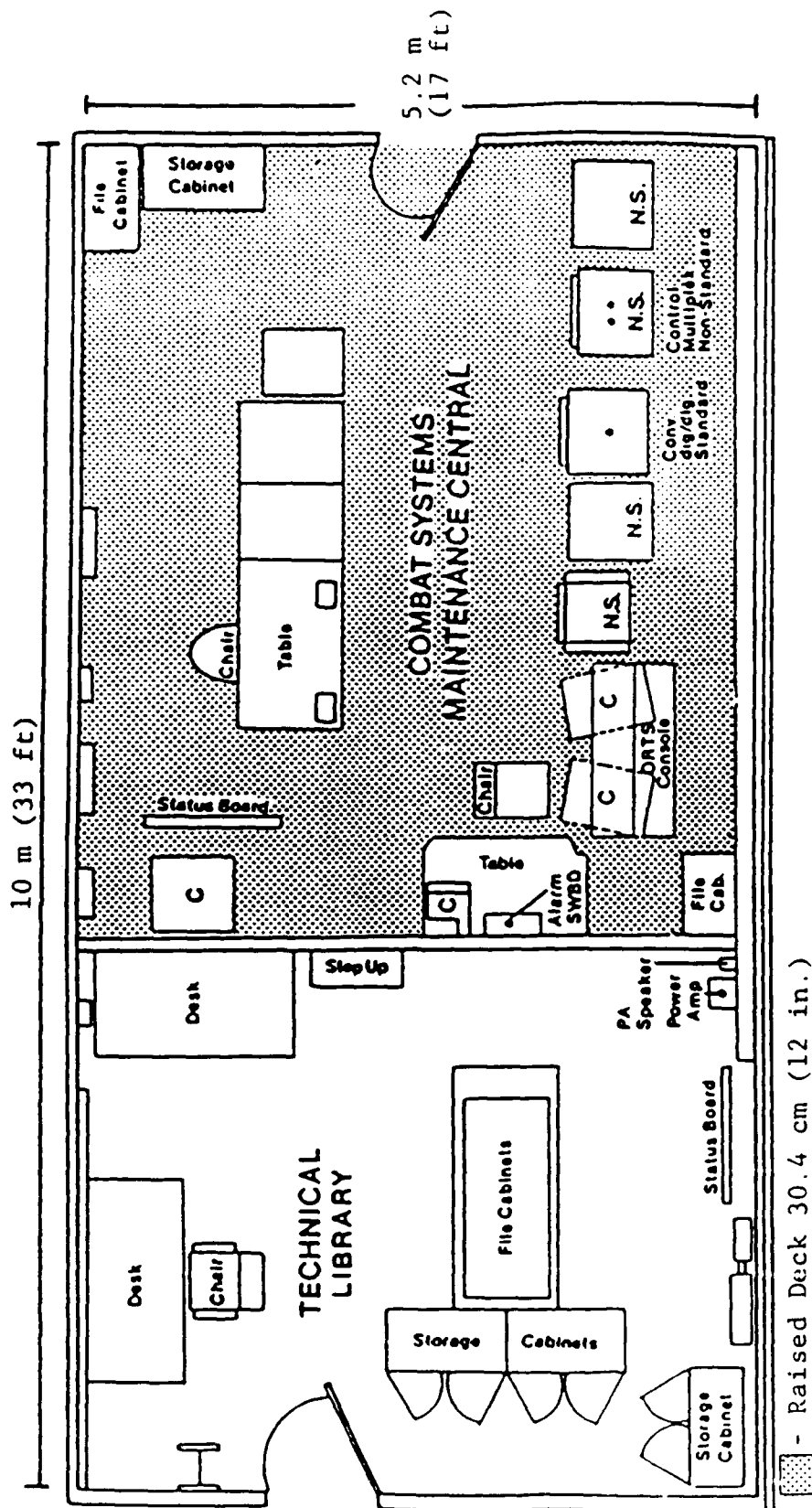


Fig. 2 - Plan view, Combat Systems Maintenance Central & Technical Library, Aegis Training Facility, Moorestown, NJ

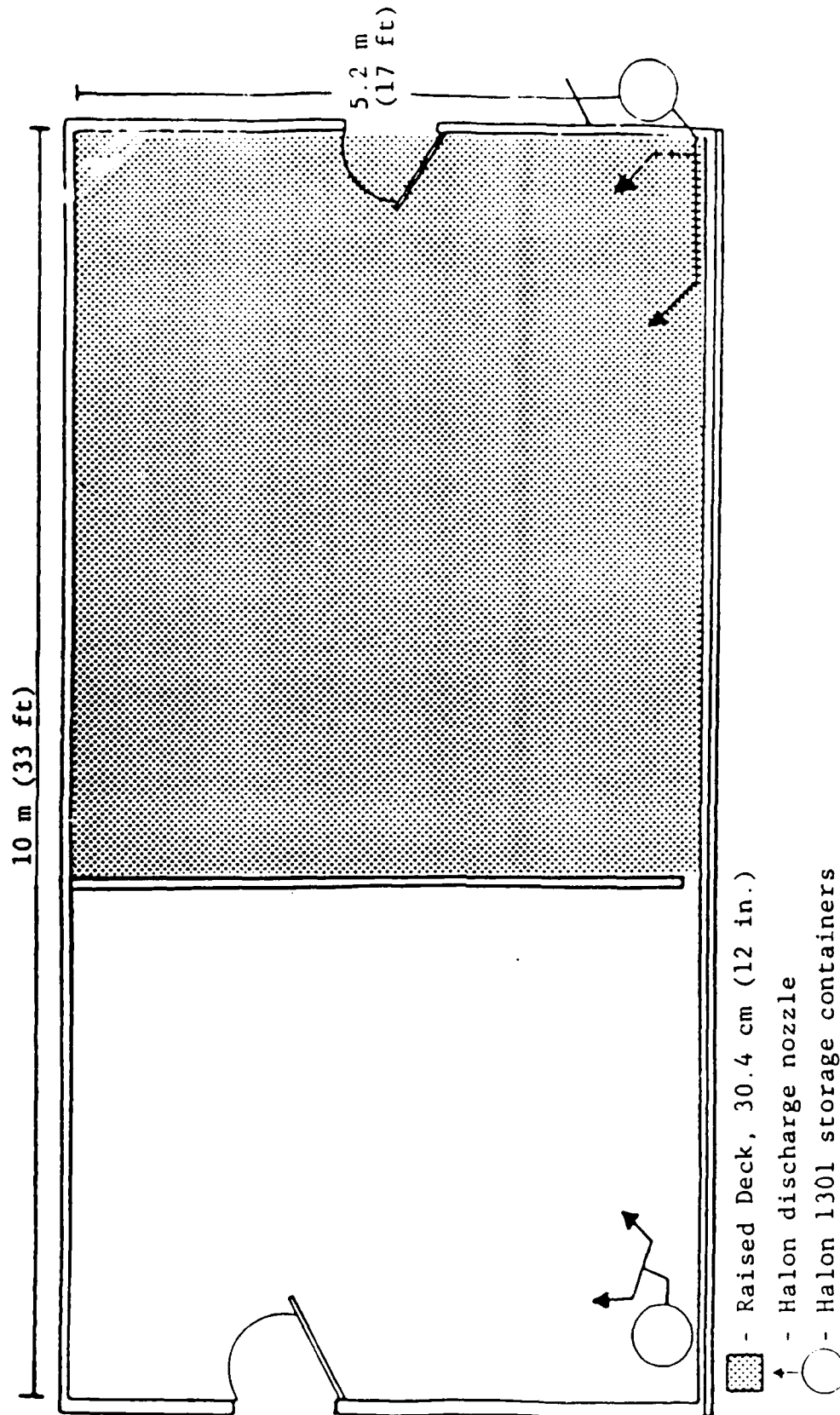


Fig. 3 - Halon 1301 total flooding system, Combat Systems Maintenance
Central & Technical Library, Aegis Training Facility, Moorestown, NJ

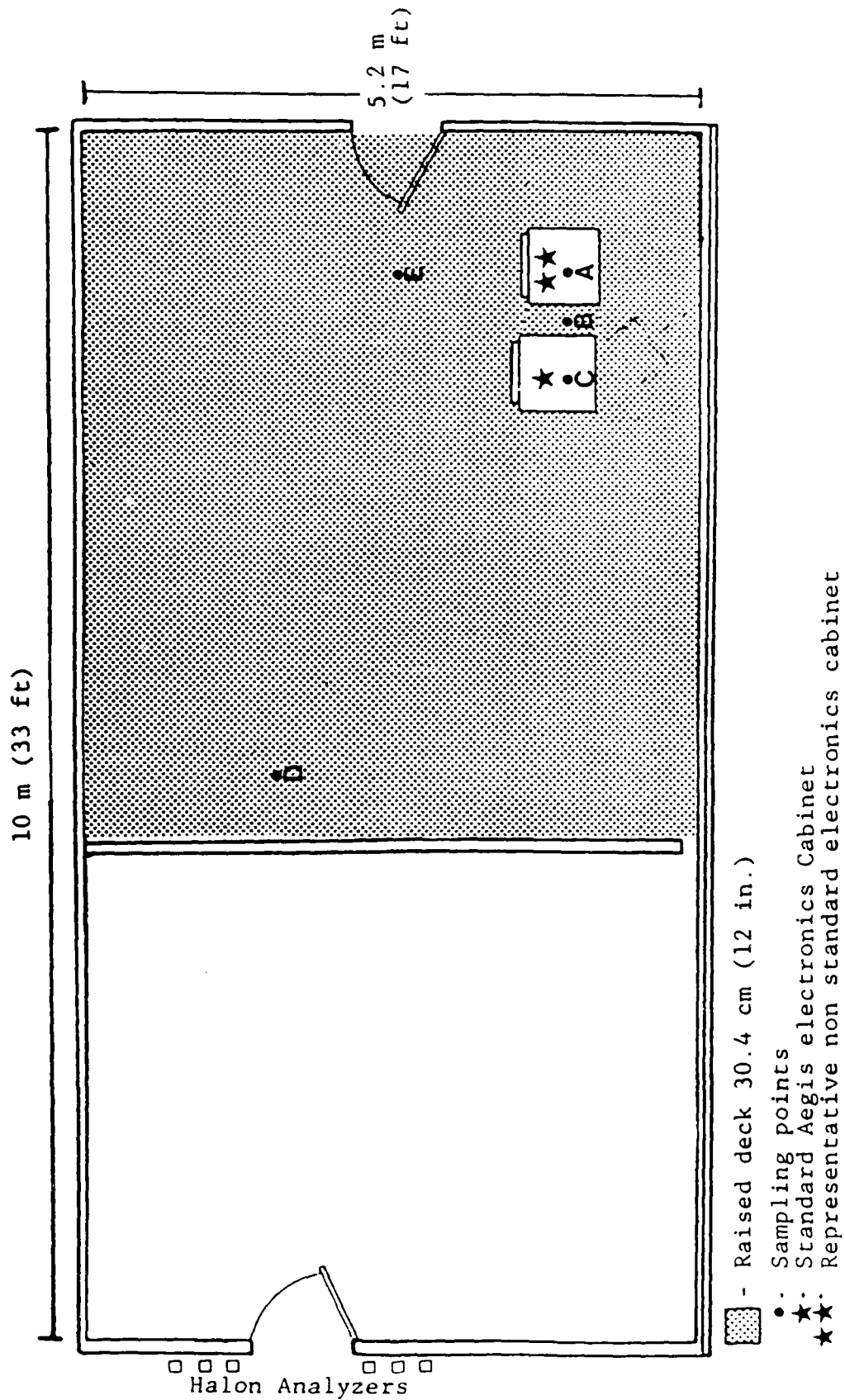


Fig. 4 - Halon 1301 instrumentation arrangement, Combat Systems Maintenance Central & Technical Library, Aegis Training Facility, Moorestown, NJ

The tubes exited the enclosure through an existing air duct, with the duct being resealed with tape. Samples were analyzed from each sampling probe every 5 seconds. The corresponding concentrations were immediately plotted on strip recorders attached to each analyzer.

A top view of all the specific sampling points is also shown in Fig. 4. The vertical sampling trees are shown as A, B, C, and D. Position E is a stand alone sampling probe located under the raised deck area. Figure 5 is a side view showing vertical sampling trees A, B, and C. Also shown are the two electronic cabinets selected for Halon penetration tests. These cabinets were:

1. Converter digital/digital (standard Aegis cabinet); and
2. Controller multiplexer (non-standard cabinet).

Both of these cabinets are about the same size, 1.8 m (6 ft) x .61 m (2 ft) x .74 m (2.5 ft) and were located adjacent to each other. This arrangement was quite convenient because it allowed direct comparisons of Halon 1301 penetration between a Standard Aegis electronics cabinet and a non-standard electronics cabinet. Probes shown in Fig. 5, numbered M11, M22, and M33, represent external cabinet probes located in the space between the cabinets. These probes were positioned at locations adjacent to internal cabinet probes. This provided a direct comparison of the internal and external Halon 1301 concentration profiles. In addition, probe 13 was placed beneath the raised deck directly below the two instrumented cabinets.

The concentration profile was also monitored at the vertical sampling tree D. Vertical sampling tree D can be seen in Figs. 4 and 6. This vertical sampling tree extended from the floor to the ceiling, starting with a probe located 1.37 cm (1/2 in.) below the ceiling. Others were located in .6 m (2 ft) increments progressing towards the floor. The sampling probes were held in this position by attaching them with tape to an existing structural support column.

Halon concentrations were also monitored in three areas under the raised deck. One probe K20 formed the bottom-most probe of vertical sampling tree D. This probe was located in the open, 15.2 cm (6 in.) off the actual floor. Another probe, K1, was placed in a large cable bundle under the raised deck, shown as position E in Fig. 4. The final probe, K13, was placed under the raised deck directly below the instrumented cabinets as shown in Fig. 5.

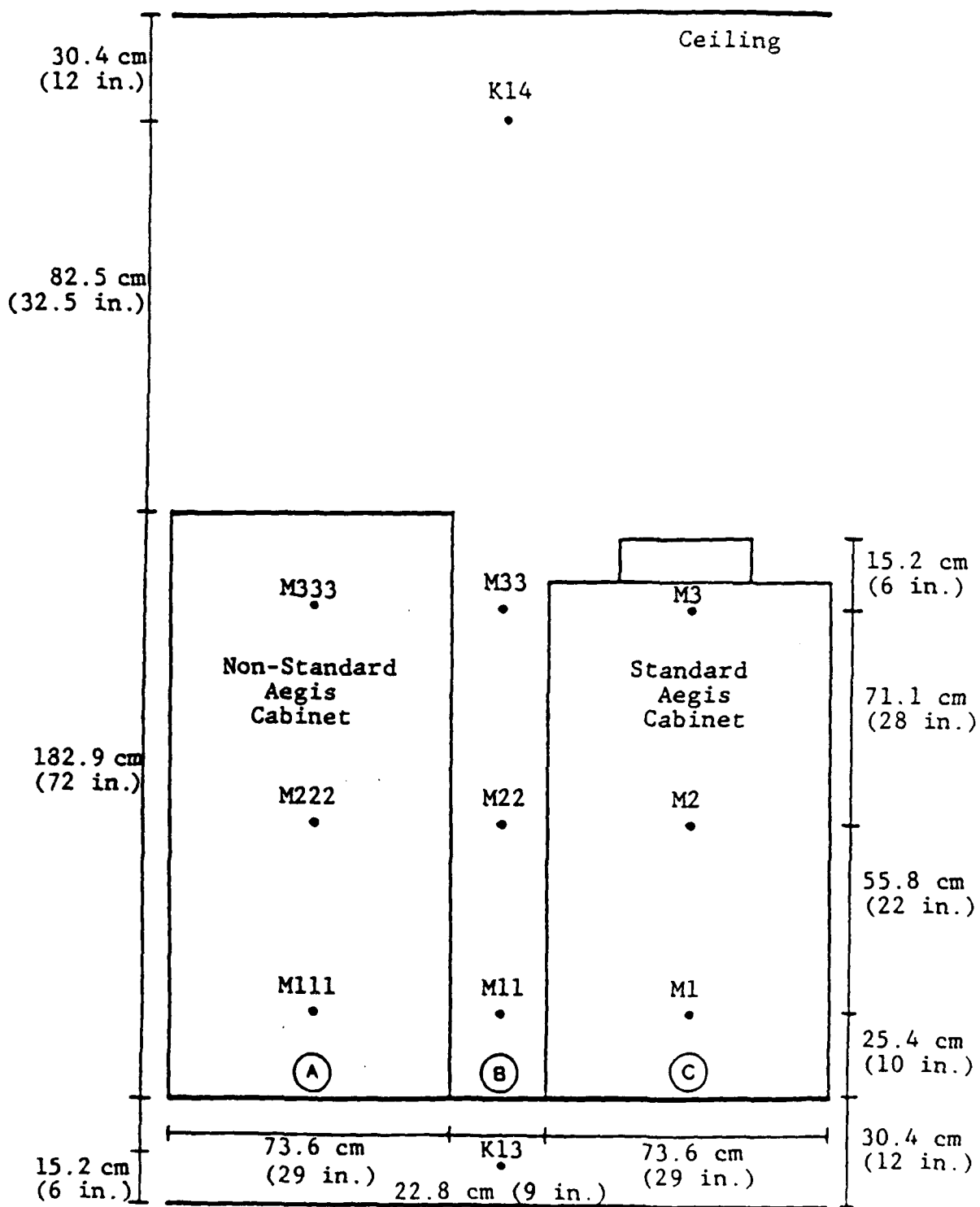


Fig. 5 - Halon 1301 vertical sampling trees A, B, and C

SAMPLING TREE D

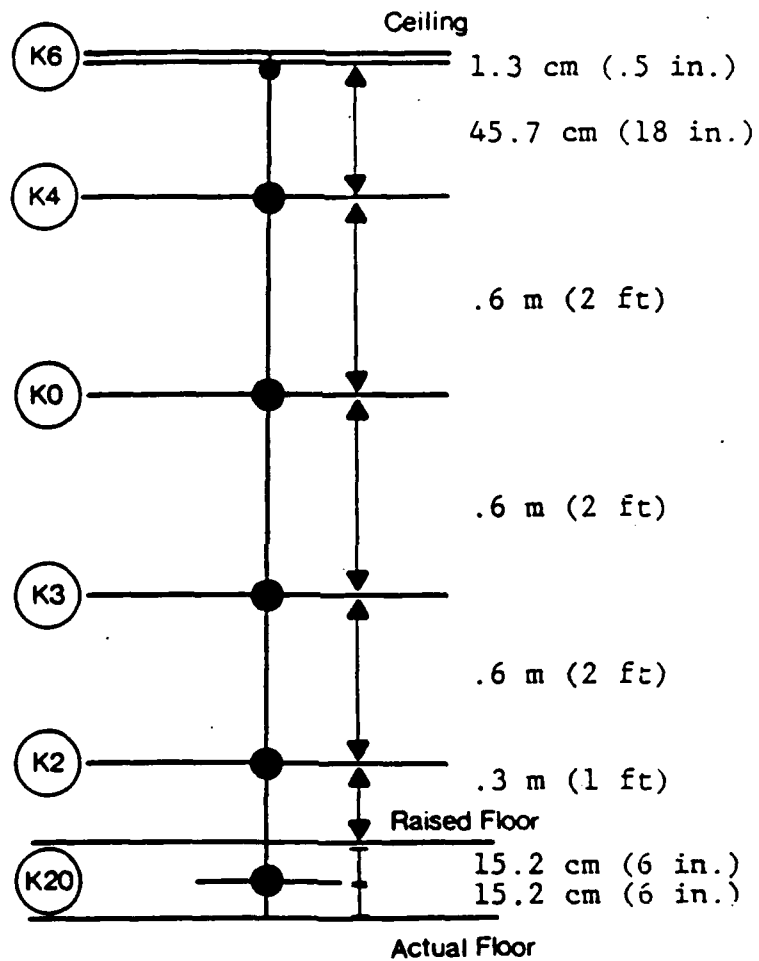


Fig. 6 - Side view of vertical sampling tree from floor to ceiling

5.0 PROCEDURE

The test procedure required two complete Halon 1301 system discharges as follows: for Test #1 the internal cabinet fans were turned off, and for Test #2 they were left on. Test 1 simulated the current shipboard emergency procedure of initially securing the space power upon detection of a fire. Test 2 simulated a possible Halon 1301 discharge before the power could be secured. This procedure will permit direct evaluation of the effects on the Halon 1301 concentrations produced by the operation of the interior cabinet cooling fans. The dampers in the HVAC ducting terminating in the space were all closed and the ventilation system secured for each test. This particular space enabled independent control over internal cabinet fans and the main space ventilation system.

6.0 RESULTS

Figures 7 through 12 represent the plotted data obtained from various vertical sampling positions A, B, and C. These figures present comparisons of the time based Halon 1301 concentrations produced inside the instrumented cabinets with those recorded at the same external positions. Figures 7, 8, and 9 show data that was obtained during Test #1 (internal cabinet cooling fans off), while Figs. 10, 11 and 12 represent data obtained during Test #2 (internal cabinet cooling fans on). Careful review of these figures reveals several predominate trends, namely:

1. The data show that Halon 1301 rapidly entered the two instrumented electronic cabinets, regardless of the operation of the internal cooling fans. During both tests the design concentration of 6% Halon 1301 was obtained inside of the cabinets in less than 10 s following system discharge.

2. These data also show a gradual reduction in the Halon 1301 concentration profile beginning at the highest point. Verification of this can also be seen in Figs. 13 and 14, which represent data obtained in Test #1 and Test #2, respectively. Each figure shows the vertical concentration profile of Halon 1301 recorded at various levels above the actual floor. The sampling levels were approximately 3.0 m (10 ft), 1.8 m (6 ft), 1.2 m (4 ft), .61 m (2 ft), and 15.2 cm (6 in.). These vertical levels correspond to sampling points shown on Fig. 6 as K6, K0, K3, K2, and K20, respectively. Evaluation of Figs. 13 and 14 show a distinct time based reduction in the Halon 1301 concentration starting at the ceiling and progressing towards the floor. This descending interface is typical of Halon 1301 leakage from compartments. The time at which the Halon 1301 concentration profile descends is controlled predominately by breaches in

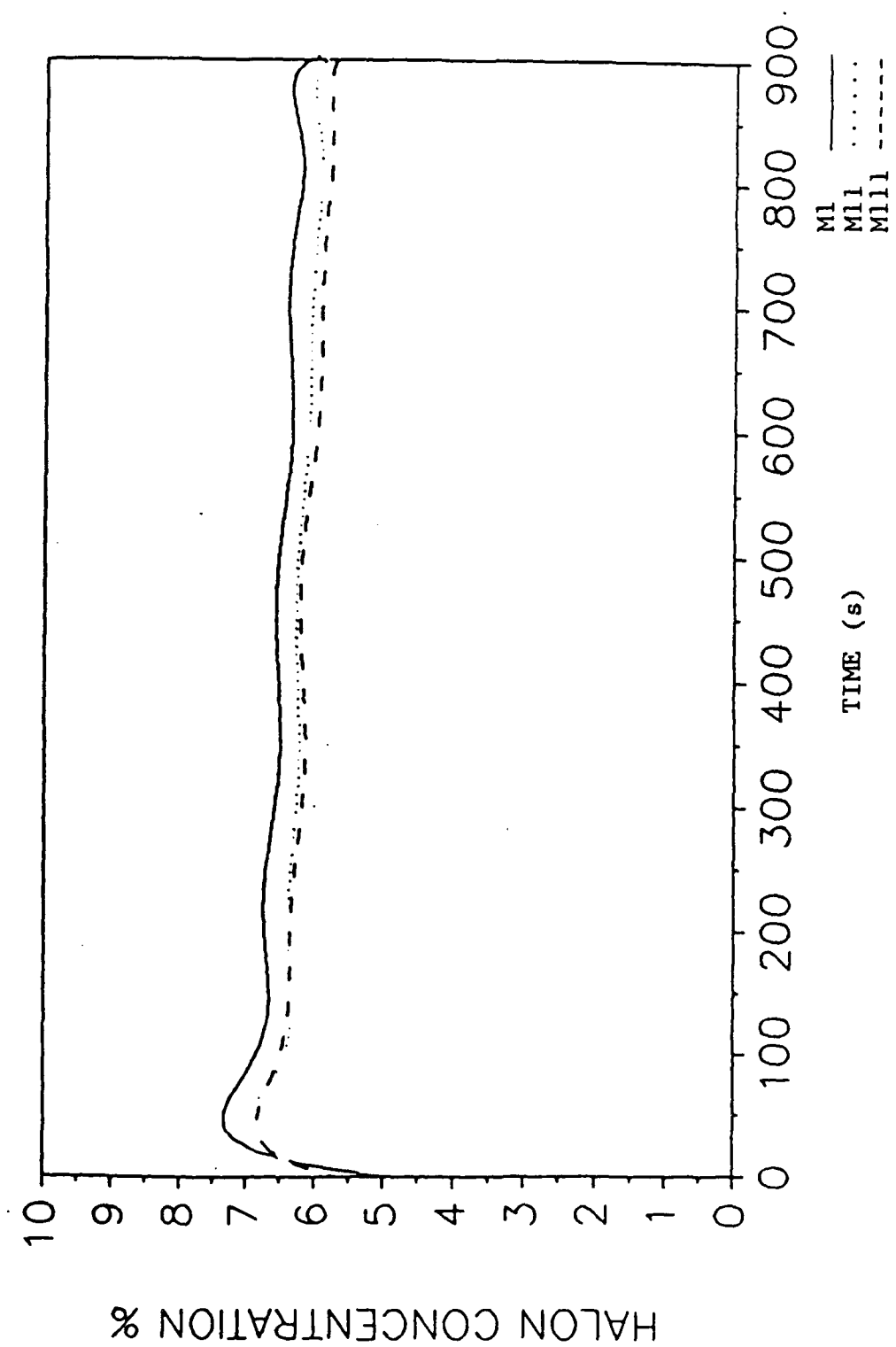


Fig. 7 - Test 1, Halon concentrations at vertical sampling trees
A,B,C, 25.4 cm (10 in.) above raised deck, fans off

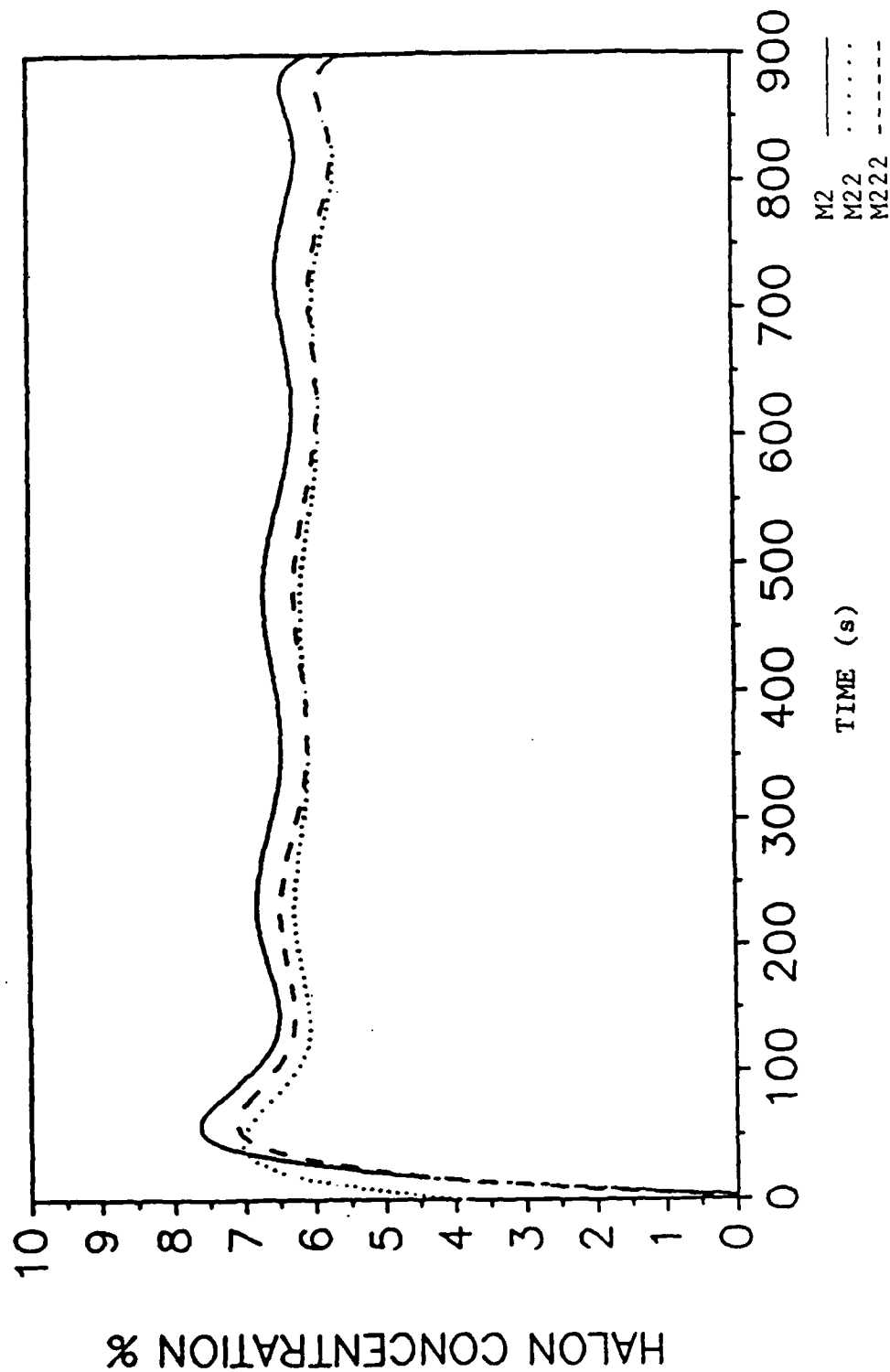


Fig. 8 - Test 1, Halon concentrations at vertical sampling trees A,B,C, 81.3 cm (32 in.) above raised deck, fans off

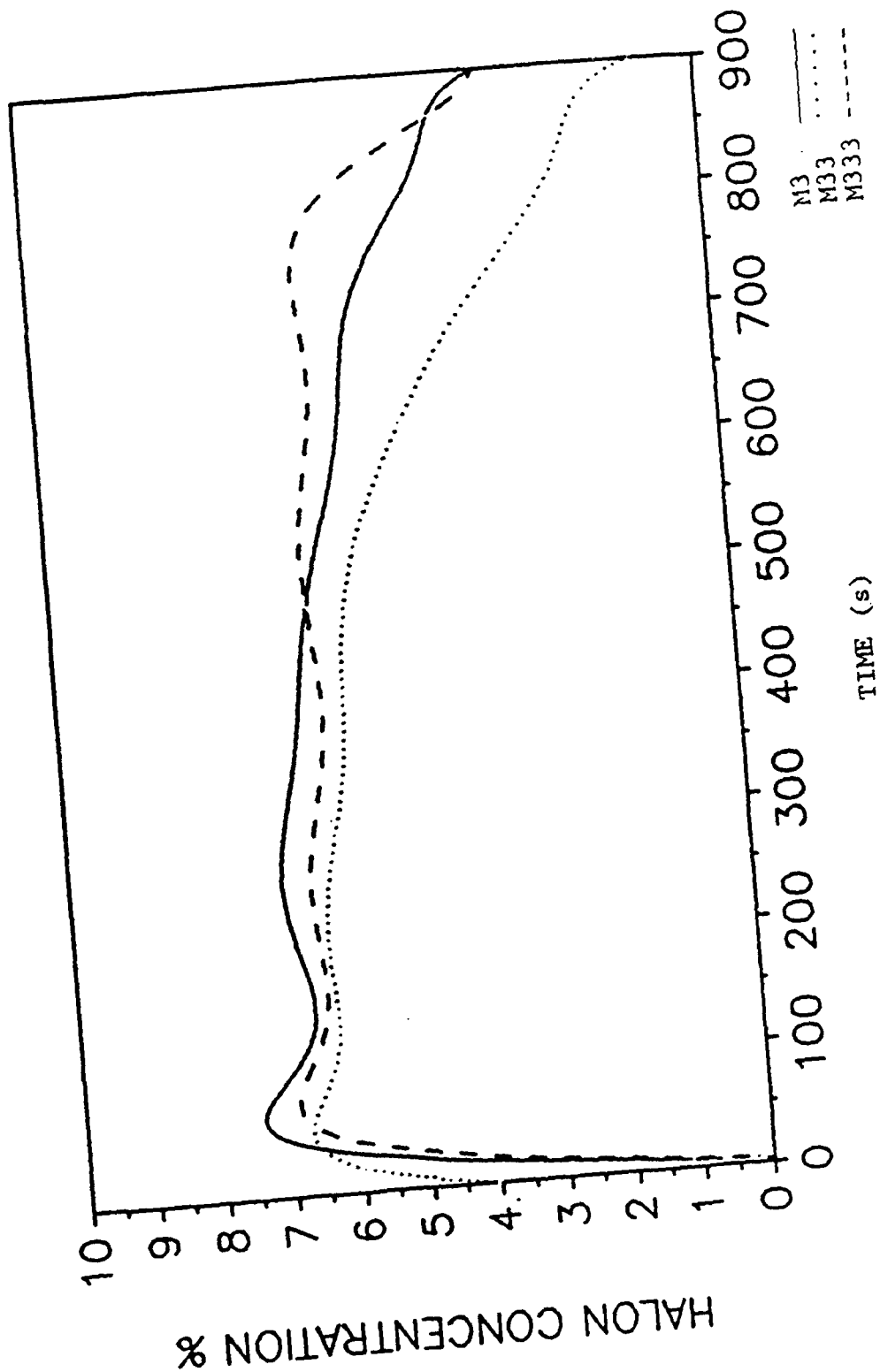


Fig. 9 - Test 1, Halon concentrations at vertical sampling trees A,B,C, 152.4 cm (60 in.) above raised deck, fans off

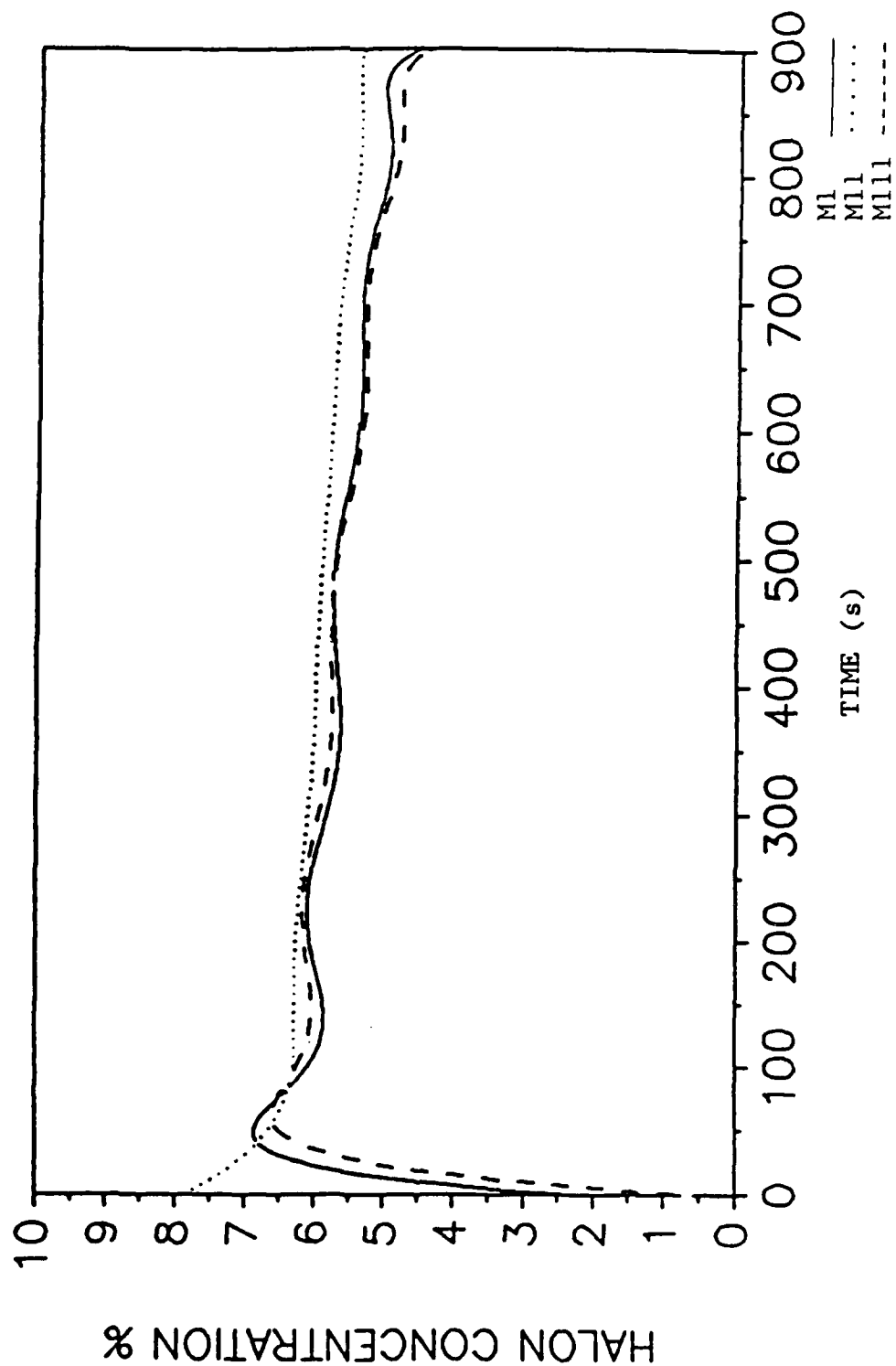


Fig. 10 - Test 2, Halon concentrations at vertical sampling trees A,B,C, 25.4 cm (10 in.) above raised deck, fans on

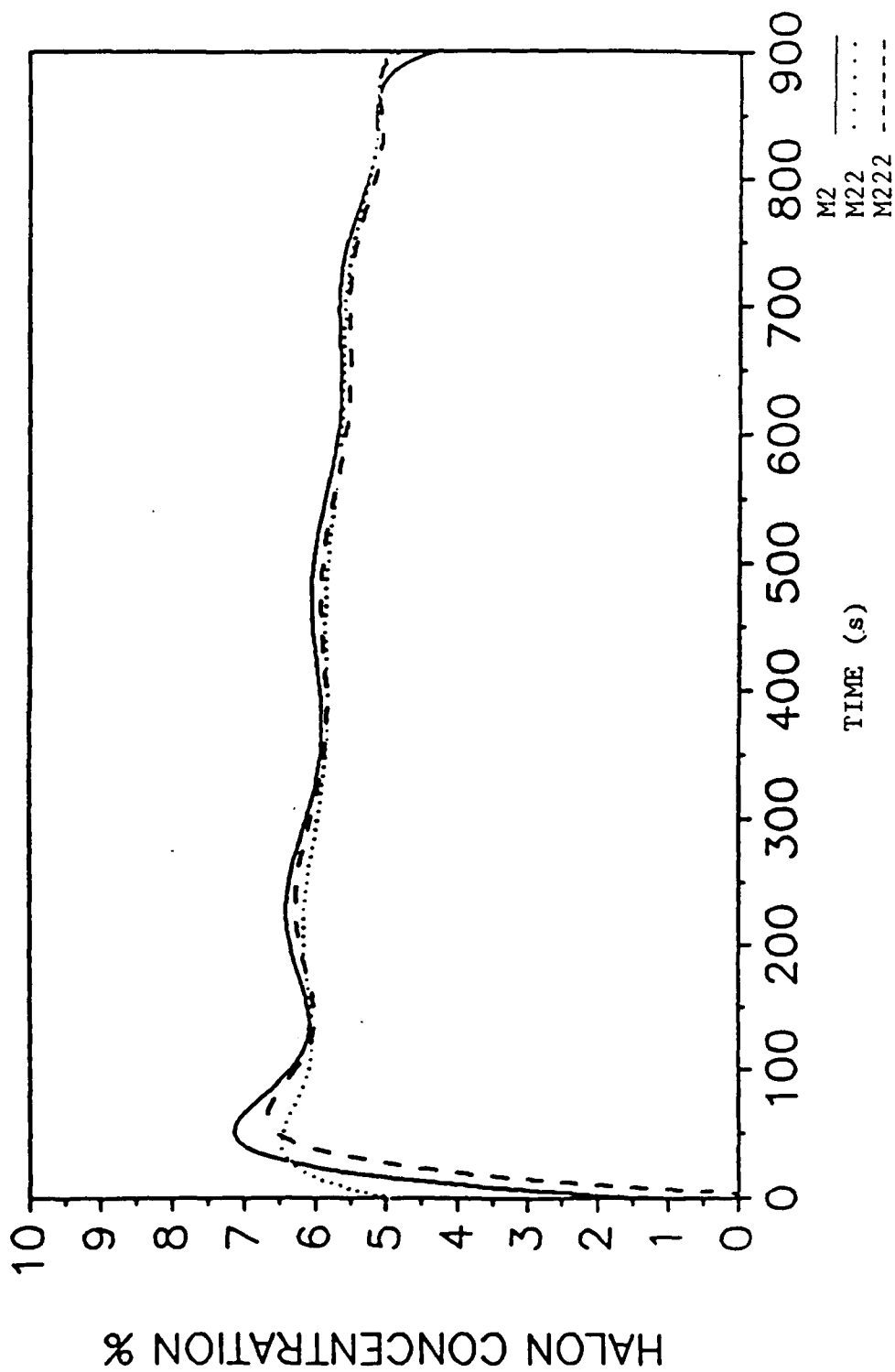


Fig. 11 - Test 2, Halon concentrations at vertical sampling trees A,B,C, 81.3 cm (32 in.) above raised deck, fans on

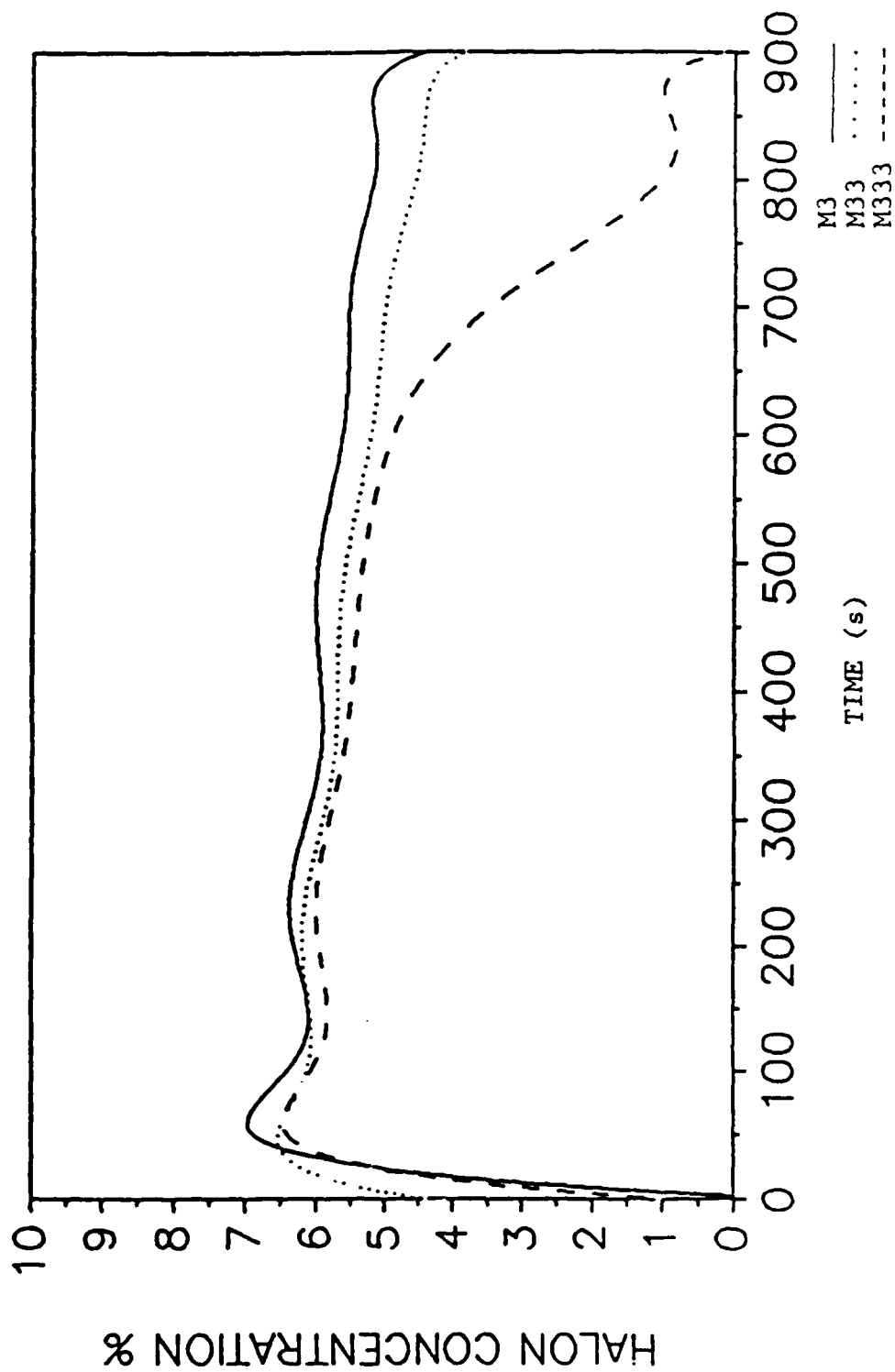


Fig. 12 - Test 2, Halon concentrations at vertical sampling trees A,B,C, 152.4 cm (60 in.) above raised deck, fans on

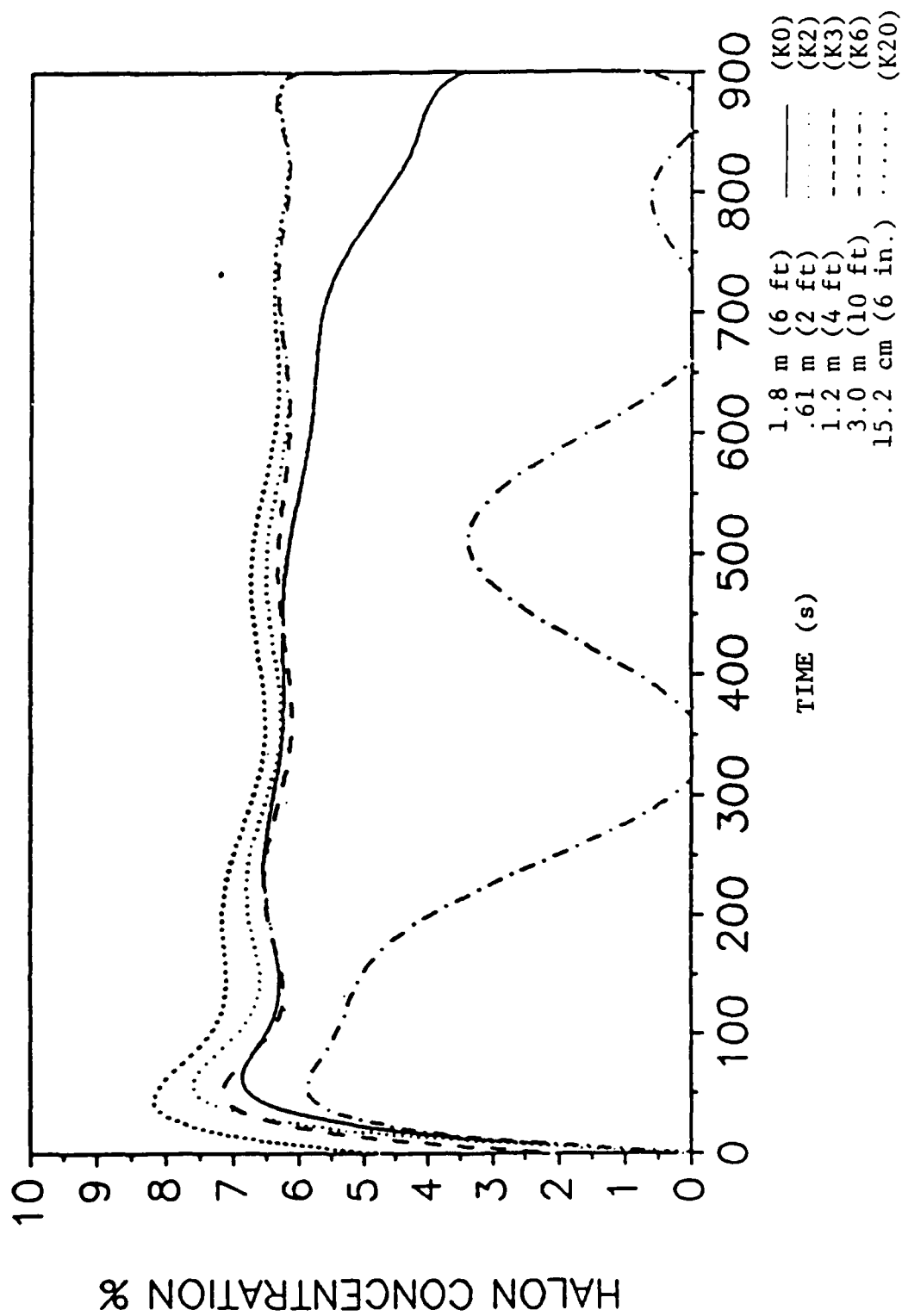


Fig. 13 - Test 1, Halon concentrations at vertical sampling tree D, fans off

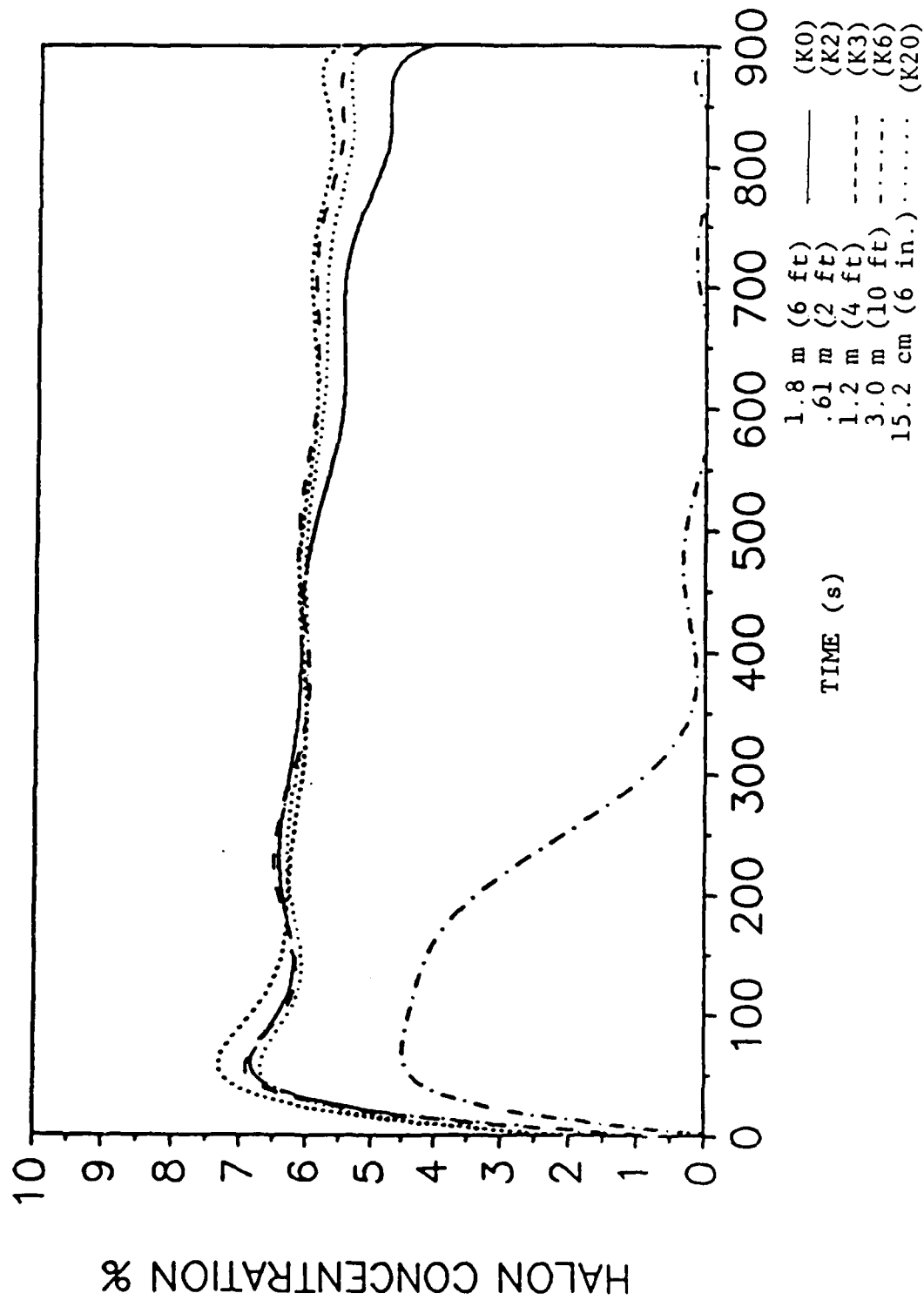


Fig. 14 - Test 2, Halon concentrations at vertical sampling tree D, fans on

the enclosure's air tightness. Hand held Halon 1301 analyzers were used outside the compartment to check for leaking areas during each test. Minor leaks were detected near the floor during each test.

In addition, during Test #1 it was noted that sampling point K0, which is located approximately 1.8 m (6 ft) above the actual floor, showed a consistently low localized Halon 1301 concentration. A post-test investigation showed that a closed loop recirculation system had inadvertently been left in operation during Test #1. This could explain the low Halon 1301 concentrations recorded by sampling point K0. The recirculation duct was approximately 1.5 m (5 ft) away from this sampling point and discharged air directly towards it. This could also explain the slightly higher and prolonged Halon 1301 concentrations recorded during Test #1. The operating recirculation system served as an excellent mixer for the Halon 1301/air mixture. Prior to conducting Test #2 this duct was sealed and other recirculation fans secured.

Figures 15 and 16 show data from sampling points K1, K13, and K20. These sampling points were all located beneath the raised deck area, as shown in Figs. 4, 5 and 6. Sampling point K1 is located inside a large cable bundle, while K13 and K20 are positioned in open air 15.2 cm (6 in.) above the actual floor. Review of Figs. 15 and 16 reveal immediate Halon 1301 penetration into the instrumented cable bundle. All under floor concentrations were well in excess of the 6% design concentration. The reduction shown in Fig. 15 of probe K20 occurred when sampling point K1 and K0 were interchanged. This was done by the operators of the Halon analyzers to confirm the low local concentration recorded at point K0. As discussed previously, this was caused by the inadvertent operation of a recirculation duct.

The Halon 1301 concentrations produced by this total flooding system appear to be uniform. This is evidenced by the concentration profiles shown in Figs. 17 and 18. These figures, again, represent data recorded from Test #1 and #2, respectively. Figures 17 and 18 were constructed by superimposing selected data obtained from sampling positions A, B, C, and D. The specific positions were all at the same approximate vertical elevation 1.2 m (4 ft) above the actual floor. Each figure shows recorded data obtained from sampling points M11, M22, M33, and K3. The intent was to show any concentration variations produced 1.2 m (4 ft) above the actual floor at remote locations. The excellent agreement of the data shown in Figs. 17 and 18 also lends credibility to all the results present herein. That is, it appears there were no localized pockets of Halon 1301.

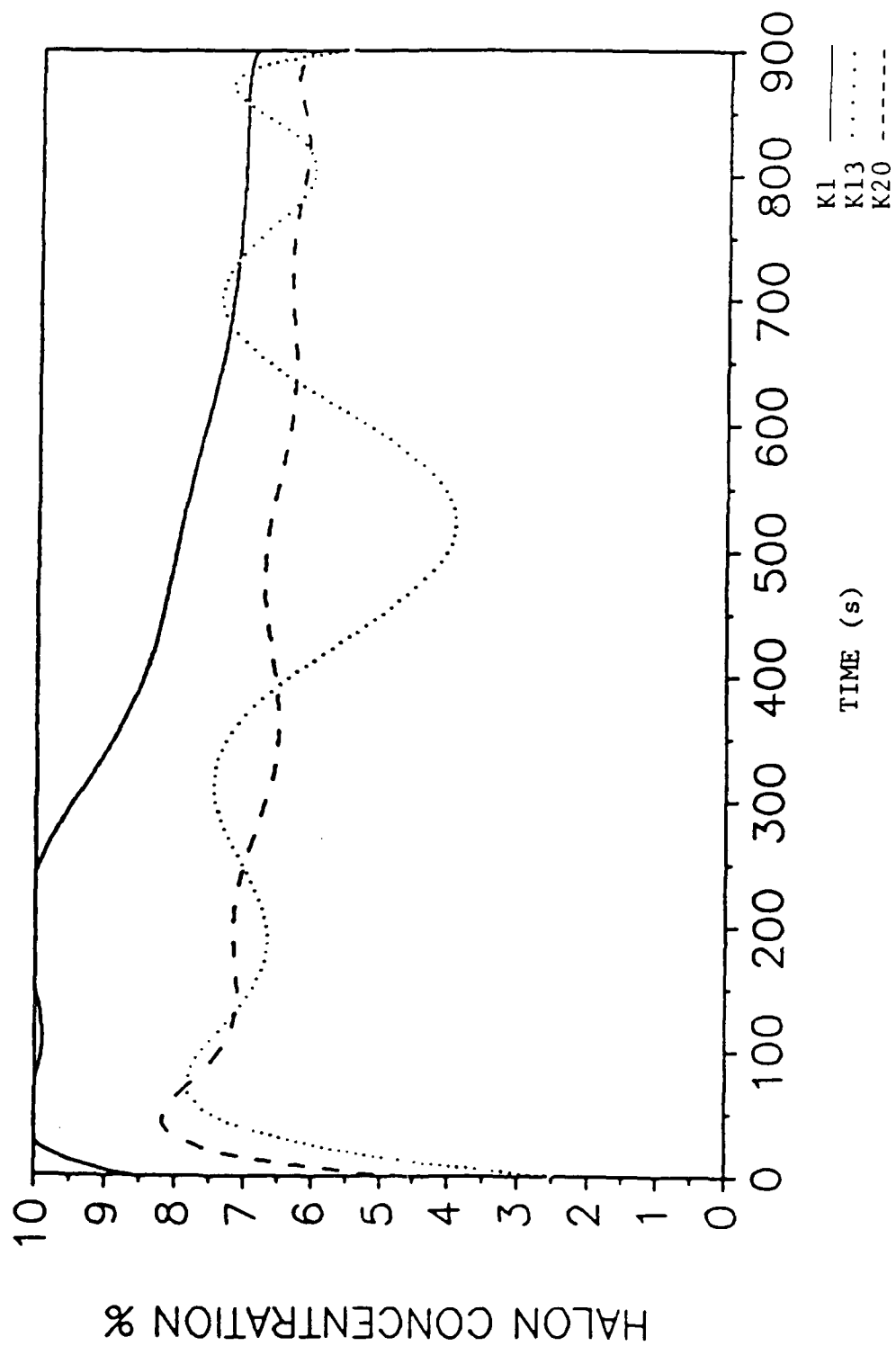


Fig. 15 - Test 1, Halon concentrations beneath raised deck, fans off

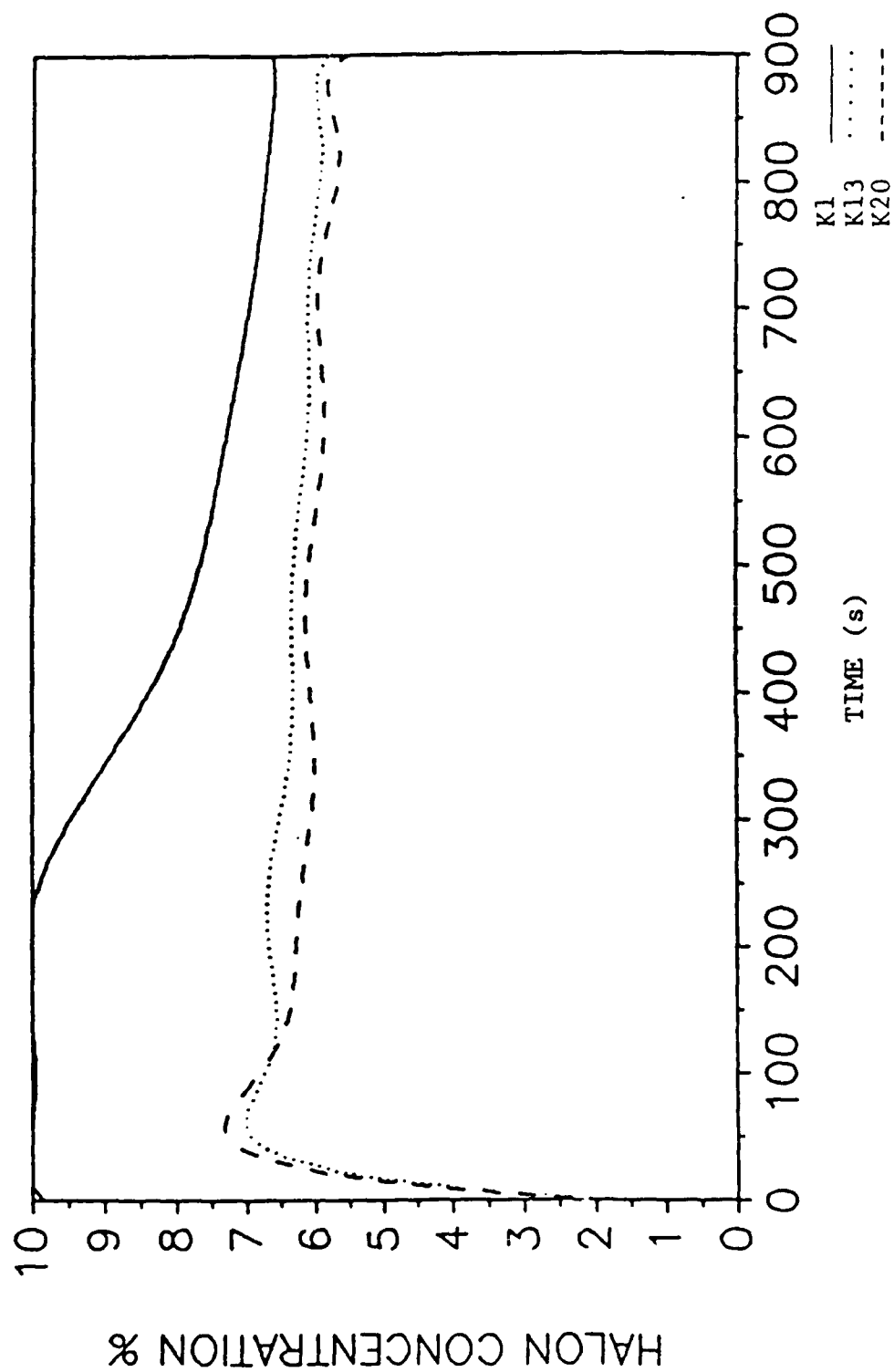


Fig. 16 - Test 2, Halon concentrations beneath raised deck, fans on

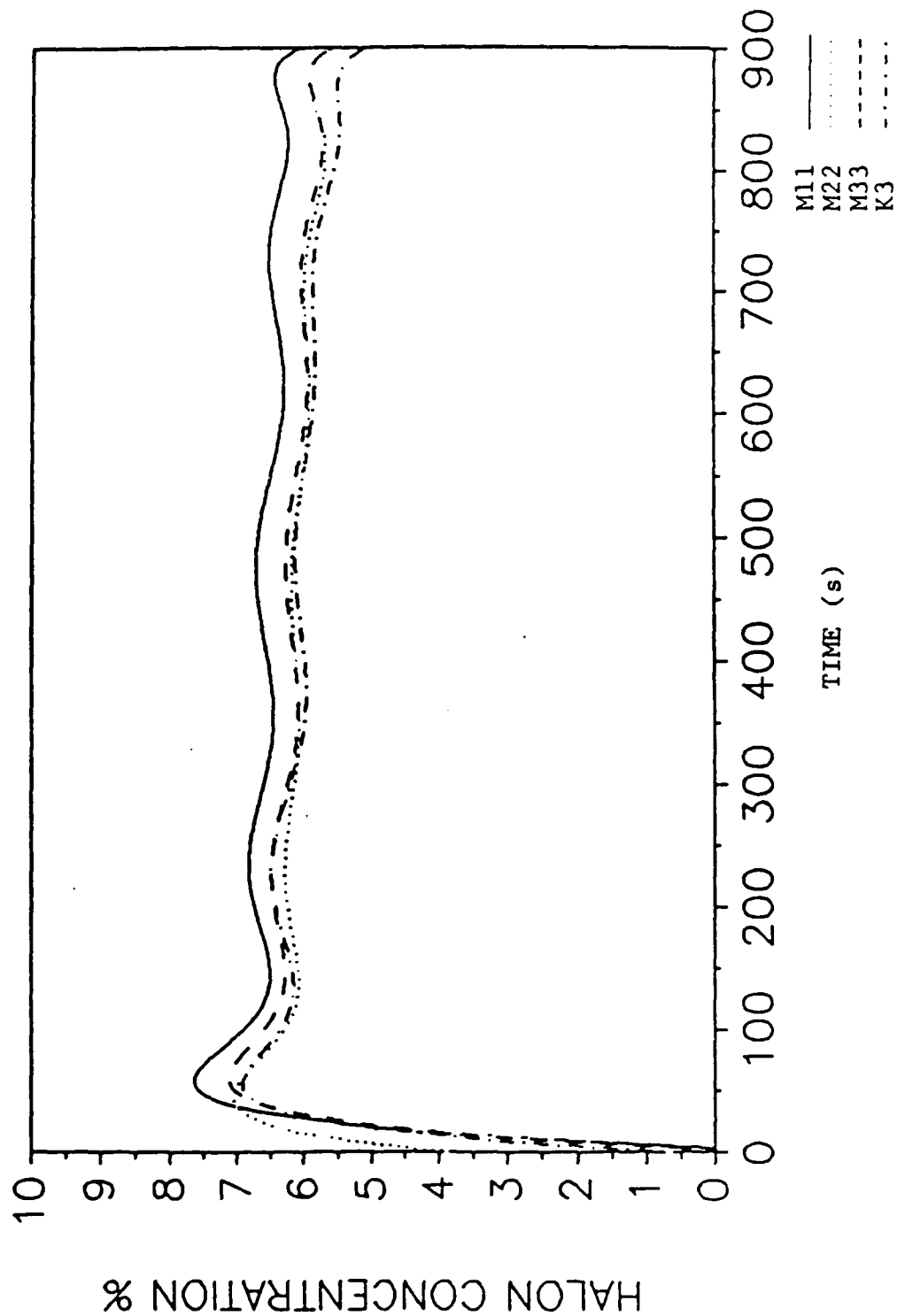


Fig. 17 - Test 1, Halon concentrations 1.2 m (4 ft) above actual floor, fans off

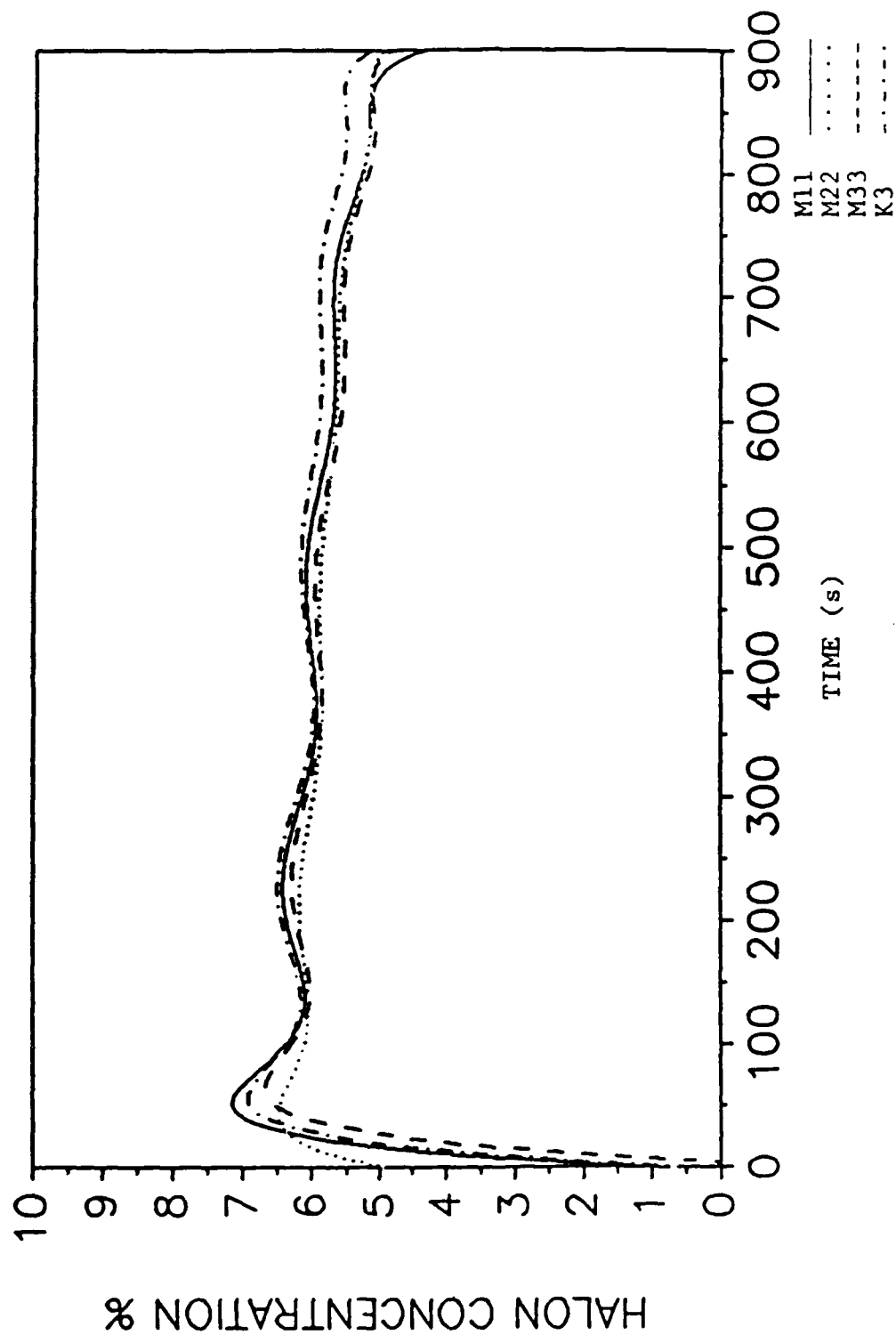


Fig. 18 - Test 2, Halon concentrations 1.2 m (4 ft) above actual floor, fans on

7.0 CONCLUSIONS

The conclusions determined as a result of these tests can be summarized into four major topics. They are:

1. Under normal conditions, Halon 1301 will penetrate typical shipboard electronic cabinets in sufficient time and concentration to successfully extinguish a potential fire.
2. Under normal conditions, Halon 1301 will penetrate a typical shipboard cable bundle, that is secured to the space floor, in sufficient time and concentration to successfully extinguish an internally developed fire. However, this may not be the case for cable bundles secured to the walls or ceiling of the space.
3. Reduction in Halon 1301 time based concentration profiles begins near the enclosure ceiling and progresses towards the floor. The impact of the profile can be greatly effected by breaches in the enclosure's air tight integrity. As a result of this action, concern must be expressed regarding the vertical height of any combustible loading. For example, wall and ceiling mounted cable arrays may never totally experience the designed Halon 1301 concentration for the required time duration.
4. Continuing efforts must be maintained to ensure the air tight integrity of the enclosure. Casual penetrations of the enclosure boundary caused by retrofit of new equipment can have drastic effects on the performance of a Halon 1301 total flooding system.

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